Correlation of Renal Doppler Ultrasound with Angiographic Findings in the Diagnosis of Renal Artery Stenosis

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ABSTRACT

Background. Renal artery stenosis is the most common cause of secondary hypertension. Established investigative procedures to detect renal artery stenosis include catopril renal scintigram, magnetic resonance angiography and abdominal angiography. The role of renal Doppler ultrasound in the diagnosis of renal artery stenosis is evaluated in this study.

Methods. We studied 798 patients referred for renal Doppler ultrasound over a 2-year period at the Singapore General Hospital. There were 17 positive Doppler and 2 negative Doppler with angiographic correlations.

Results. Fifteen of the 17 patients referred with positive renal Doppler examination for renal artery stenosis were confirmed by angiographic examinations. The 2 negative Doppler examinations were also confirmed by angiographic examinations. Our findings are consistent with research done by other authors.

Conclusion. Renal Doppler ultrasound is an accurate, reliable, non-invasive diagnostic tool in screening for renal artery stenosis.

Keywords: peak systolic velocity, renal artery stenosis, renal Doppler

INTRODUCTION

Although the prevalence rate of renal artery stenosis in the aetiology of hypertension is only 2 to 4 % in the general population, it is listed as being the most common cause of secondary hypertension.[1,2] Established investigative procedures for renal artery stenosis include catopril renal scintigram and magnetic resonance (MR) angiography (contrast-enhanced MRA sequence), with the latter comparing favourably with abdominal angiography, which is the gold standard for final confirmatory diagnosis.

Renal Doppler ultrasound has also been used in the diagnosis of renal artery stenosis but is reportedly "less reliable" when compared with the investigative procedures mentioned above.[1] Our experience and studies by other authors have, however, proved this to be otherwise.[3-5]

METHODS

We reviewed the records of 798 patients who underwent renal Doppler ultrasound examinations at the Department of Diagnostic Radiology of the Singapore General Hospital from March 2000 to March 2002. Of the 798 patients studied, 19 renal Doppler ultrasound examinations for renal artery stenosis had angiographic follow-up (17 had abdominal angiograms while 2 had MR angiograms). Of these 19 patients, 13 were Doppler ultrasound examinations of transplant kidneys while 6 were examinations of native kidneys. Four of these patients (SBL, LSH, LHP, KCH) had records prior to March 2000 which were used in this study. One patient, THC, who had a repeat Doppler in October 2002 with angiographic confirmation the following month, was also included in our study. Seventy-seven other patients who had positive or suspicious renal Doppler findings of renal artery

Table 1. Correlation of positive renal Doppler findings with angiography in relation to renal artery stenosis.

Patient/Transplant or Native Kidney	Date/Ultrasound Doppler	Date/Angiography	Date/MR Angiography	Further Follow-Up
TYM (Tx kid)	22/4/00 – Increased (PSV) of proximal TxRA	27/4/00 – Significant RAS (80%) of proximal anastomosis Tx RA		11/5/00 – 20 % residual stenosis after renal angioplasty
SBL (Tx Kid)	5/8/99 – Recurrent stenosis at the middle segment of the TxRA	5/11/99 – Significant re-stenosis of the TxRA at the anastomotic site		
LSH (Tx Kid)	31/5/00 – PSV of Tx Kid 2 m/sec at the anastomosis	19/1/01 – Tight stenosis in the RA at its anastomotic site and in the external iliac artery.		
SK (Nav Kid)	5/1/01 – PSV First RA at the origin above 3 m/sec (2 Rt RAs)	4/1/02 – Two right renal arteries are demonstrated. The artery supplying the upper pole of the right kidney demonstrates a 95% ostial stenosis.		
ARK (Nav Kid)	2/10/00 – High PSV value is elicited in the mid portion of the Rt RA		15/1/01-No Focal stenosis seen in the renal arteries.	
LPS (Nav kid)	10/10/00 – PSV of the left RA origin is above 4 m/sec	13/2/01 – Severe (>90%) left RA focal stenosis adjacent to artery origin.		
OCK (Tx Kid)	20/3/02 – PSV of TxRA anastomotic site 2.6 m/sec	21/5/02 – There is a smooth 75% concentric stenosis in the proximal portion of the donor RA.		The donor artery stenosis was readily balloon dilated.
TCJ (Tx Kid)	8/2/02 – PSV main RA to the Tx Kid at the anastomosis above 2 m/sec.	9/4/02- Stenosis immediately beyond the anastomosis of the graft artery to the recipient external iliac artery.		

stenosis did not have any angiographic follow-up to date. One hundred and thirty-eight of the 798 patients had unsatisfactory or sub-optimal renal Doppler examinations.

RESULTS

Of the 17 cases of positive renal Doppler findings of renal artery stenosis, 15 were confirmed by abdominal angiography, 1 (VSR) had a negative correlation with abdominal angiography, while 1 (ARK) had a negative correlation with MR angiography (Tables 1 and 2).

One patient, KCH, who had a positive renal Doppler finding of renal artery stenosis confirmed by abdominal angiogaphy, had a normal peak systolic velocity (PSV) but an abnormal spectral waveform (delay in the systolic acceleration time). This was correctly diagnosed as being suggestive of renal artery stenosis.

There were 2 patients with negative renal Doppler findings who had angiographic confirmations (NSE and TSK). In keeping with the negative renal Doppler findings, the angiographic findings (abdominal and MR angiography) were negative for renal artery stenosis.

DISCUSSION

Colour Doppler sonography is used to detect flow direction and frequency shift in real time (in the area of interest). Colour Doppler displays an average frequency shift which is proportional to the flow velocity while spectral Doppler shows an entire spectrum of Doppler frequency shifts which includes the peak frequency shift or peak velocity.[6]

Renal Doppler imaging includes Colour Doppler and spectral Doppler examinations of the interlobar arteries and segments of the main renal artery.

Patient/Transplant or Native Kidney	Date/Ultrasound Doppler	Date/Angiography	Date/MR Angiography	Further Follow-Up
GAH (Tx Kid)	21/1/02 – PSV origin and near hilum of TxRA of 2.5 m/sec.	21/2/02 – The TxRA is anastomosed to the right external iliac artery with an end to side anastomosis. There is a 50% stenosis at the anastomosis.		
LSH (Tx Kid)	10/2/00 – PSV main RA of Tx Kid at the anastomosis 2 m/sec.	19/1/01 – Tight stenosis in the RA at its anastomotic site and in the external iliac artery.		
PES (Tx Kid)	15/12/00 – PSV of Tx RA anastomotic site more than 3 m/sec.	4/1/01– 50 % stenosis at the proximal segment of the RA		
LHP (Nav Kid)	29/11/99 – PSV of the proximal Lt RA is slightly raised measuring between 1.9 to 2 m/s.	14/6/00 – Abdominal Angiogram – Left RAS (mid portion of Left RA-60%) with a tight stenosis involving the origin of the lower pole segmental branch as well.		
TLT (Tx Kid)	21/9/01– PSV TxRA at anastomosis suggests significant narrowing	18/10/01– A high grade stenosis is present at the proximal TxRA.		Successfully angioplastied with a 5mm balloon with good results.
CWL (Nav Kid)	31/10/01– PSV mid portion of the Rt RA measures 3 m/sec	19/2/02 – Haemodynamically significant stenosis of the mid portion of the Right RA.		
KCH (Tx Kid)	6/3/98 – Doppler renal. transplant. Delay in the early systolic acceleration. The PSV is not increased.	13/10/98 – The smaller division of the main RA is severely stenosed (90 % at least).		4/9/01— Angioplasty. The lesion was successfully balloon dilated with 4mm and 5mm balloons.
VSR (Tx Kid)	19/7/00 – PSV of the Tx RA at the anastomos is above 2 m/sec	1/8/00 – Angiogram. Normal anastomosis between the donor RA and the recipient external iliac artery.		
THC (Tx kid)	17/10/02 – PSV of TxRA at the anastomosis greater than 2m/sec	14/11/02 – Angiogram – Two RAs, 95% stenosis of the upper and 40% stenosis of the lower anastomosis.		Angioplasty 30% residual stenosis

Abbreviations: Peak Systolic Velocity=PSV; Renal Artery=RA; Renal Arteries=RAs; Renal Artery Stenosis=RAS; Transplant Kidney=Tx Kid; Native Kidney=Nav Kid; Transplant Renal Artery=TxRA; Lt=left; Rt=Right

Note: PSV 2 m/sec reported as being suspicious of RAS in patients LSH and LHP in Table 1. Angiographic correlations were positive.

Table 2. Correlation of negative renal Doppler studies with angiographic findings in relation to renal artery stenosis.

Patient/Transplant or Native Kidney	Date/Ultrasound Doppler	Date/Angiographic Findings	Date/MR Angiographic Findings
NSE (Tx kid)	11/12/01— Normal PSV		24/10/02 — No RAS demonstrated
TSK (Nav kid)	29/9/00 — PSV less than 1 m/sec	25/4/01— Normal Bilateral renal arteriography	

Abbreviations: Peak Systolic Velocity=PSV; Transplant Kidney=Tx kid; Native kidney=Nav kid; Renal Artery Stenosis=RAS

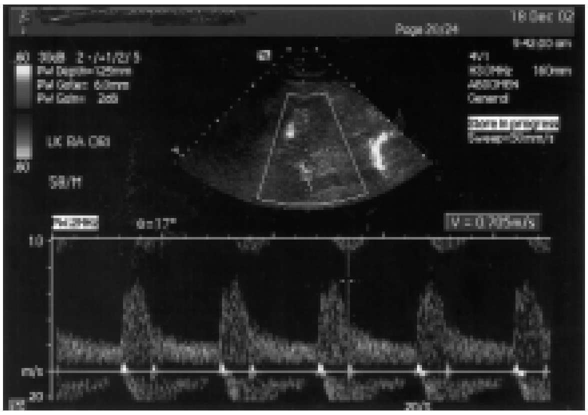

Fig. 1. Spectral waveform with normal PSV.

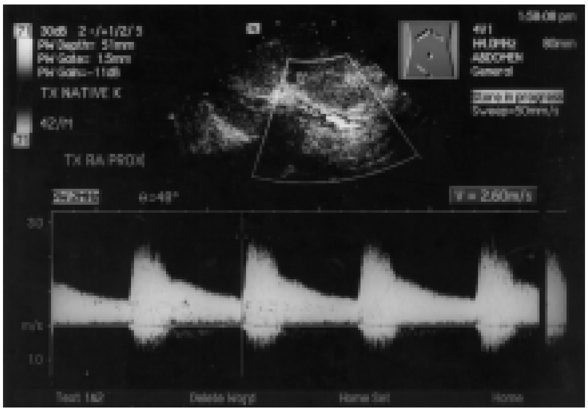

Fig. 2. Angiographically proven renal artery stenosis with a raised PSV (OCK).

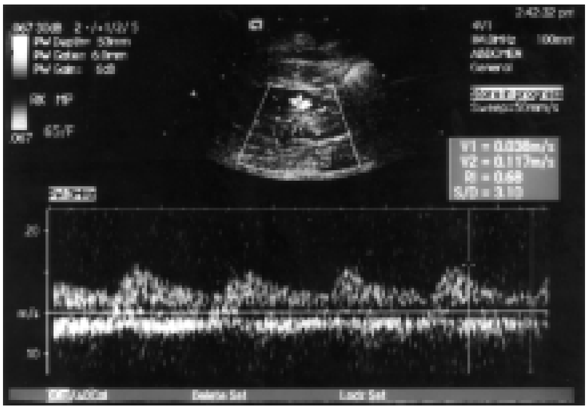

Fig. 3. Angiographically proven renal artery stenosis with a "tardus parvus" effect.

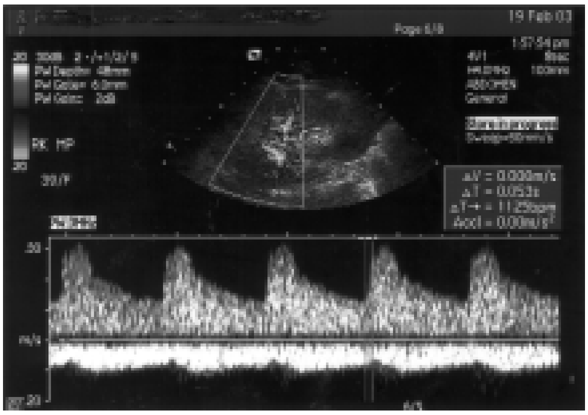

Fig. 4. Normal systolic acceleration time of less than 0.07 seconds.

The 4 criteria used for evaluating renal artery stenosis by Doppler examinations are:

1. Assessment of PSV of segments of the main renal artery
2. Intrarenal Doppler waveform analysis
3. Comparison of the renal aortic ratio (main renal artery PSV compared with aortic PSV)
4. Measurement of the systolic acceleration time

Platt reported that a PSV of greater than 180cm/sec and a renal artery/aortic ratio of greater than 3.5 were abnormal and suggestive of renal artery stenosis.[7] Williams *et al* reported that "a Peak Systolic Velocity greater than 200cm/sec is probably the most accurate test for renal artery stenosis" (Figs. 1 and 2).[8]

Intrarenal waveform analysis is an indirect method of assessing renal artery stenosis. An abnormal delayed systolic upstroke in the waveform is considered to be related to a haemodynamically important stenosis – the tardus parvus effect.[9] Tardus refers to delayed or prolonged early systolic acceleration, while parvus refers to diminished amplitude and rounding of the systolic peak.[10] The tardus parvus effect, if seen, is an accurate predictor of renal artery stenosis (Fig. 3). However, the converse is not true i.e. the absence of this effect does not effectively exclude renal artery stenosis.

Another parameter used is the systolic acceleration time. The systolic acceleration time is computed by use of vertical markers at the onset of the waveform to its first peak and should be less than 0.07 seconds. Figure 4 shows a normal waveform with a systolic acceleration time of less than 0.07 seconds.

In our department, routine renal Doppler examinations include gray scale ultrasonograms of the kidneys followed by Doppler "studies" of intrarenal perfusion showing the spectral waveforms and resistive indices of the upper and lower poles of the kidney to be examined. The PSVs of the renal artery are then measured at the origin, mid-segment and hilar region. The right kidney is usually scanned in the left posterior oblique position while the left kidney is scanned in the

Table 3. Positive predictive value of renal Doppler studies with reference to renal artery stenosis.

Renal Doppler Findings	Renal Artery Stenosis Present	Absent	Total
Positive	15	2	17
Negative	0	2	2
Total			19

Positive Predictive Value (PPV) = 15 / 15+ 2 x 100% = 88.2%

right posterior oblique position. A PSV greater than 200 cm/sec for native and transplant kidneys was taken as being suggestive of renal artery stenosis.

Accuracy of Renal Doppler Examinations in Relation to Renal Artery Stenosis

Kohler *et al* recorded a sensitivity of 84%, specificity of 97% and overall agreement with angiography of 93 %.[11] Olin *et al* also showed excellent results, with sensitivity and specificity of 98%.[3] Another study by Napoli *et al* showed favourable results with a sensitivity of 93% and specificity of 92 %.[4]

A recent advance is the use of a contrast agent in Doppler sonography for renal artery stenosis. A study by Cianci *et al* showed a higher rate of successful diagnosis (in intermediate and distal stenosis) when compared to unenhanced Doppler sonography.[5] This development could further enhance the accuracy of renal Doppler ultrasound in the diagnosis of renal artery stenosis.

Our sample study, though small, compares favourably with the studies of Kohler *et al,* Olin *et al* and Napoli *et al*. However, mention must be made with regard to the non-availability of confirmatory angiograms in a fair number of cases. It is unusual or perhaps inappropriate for an invasive study like angiography to be carried out on all patients scanned routinely for renal artery stenosis, especially in those with normal findings. Besides, some of the patients referred are clinically diagnosed as cases of chronic renal failure and normal renal Doppler examinations (in such cases) preclude further investigation in this direction. We agree that there are also a fair number of cases with positive renal Doppler examinations but without any angiographic correlations. A related prospective study would perhaps help improve on these statistics.

The positive predictive value of our study was 88.2 % (Table 3).

A high proportion of technically unsuccessful cases of renal Doppler examinations were recorded over the 2-year study period (138 out of 798, giving a failure rate of 17 %). This percentage appears to be significant. The causes of an inadequate study include patients not being able to satisfactorily hold their breath, obesity in patients, inadequate bowel preparation and poor vascular flow due to chronic renal insufficiency.

In the case of transplant kidneys, which are normally located in the iliac fossa, the short transplant artery with its relatively horizontal position makes scanning more difficult. There is, however, less need for transplant patients to adequately hold their breath.

CONCLUSION

Duplex/Colour Doppler sonography is an invaluable non-invasive tool in screening for renal artery stenosis.

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